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KEITHLEY INSTRUMENTS

T. LOUIS SNITZER CO.
ELECTRONIC ENGINEERING REPRESENTATIVES
15 NORTH 40th PLACE
PHOENIX, ARIZONA 85034
TELEPHONE 273-1673

INSTRUCTION MANUAL

MODEL 409

PICOAMMETER

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SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 409 Picoammeter measures currents over 20 ranges from 3×10^{-13} to 10^{-3} ampere full scale. Accuracy is ±2% of full scale from 10^{-3} to 10^{-8} ampere, and ±4% of full scale on the other ranges. Zero drift is less than 1% per 24 hours on all ranges except the 3×10^{-13} ampere range, where it is 3% per 24 hours.

b. The Model 409 uses an electrometer tube input with solid-state amplifiers and power supply. The amplifier circuit is completely contained in the Model 4090 Input Head.

1-2. FEATURES.

a. A zero check switch permits zeroing the meter without disturbing the circuit.

b. Long-term dc stability of the power supply is within 0.1%. Output variations are less than 0.001% for 10% line-voltage changes. The solid-state design results in less than 15 watts of power consumption.

c. A ±3 volt output at up to one milliampere drives recorders directly. Output noise is less than 1% rms of full scale on any range.

1-3. APPLICATIONS.

a. The Model 409 Picoammeter can be used for measuring leakage currents in solid-state devices, determining capacitor leakage resistance, and monitoring nuclear reactors. It can amplify and measure signals from ion gages, liquid-level gages, thickness gages, photo tubes and mass spectrometers.

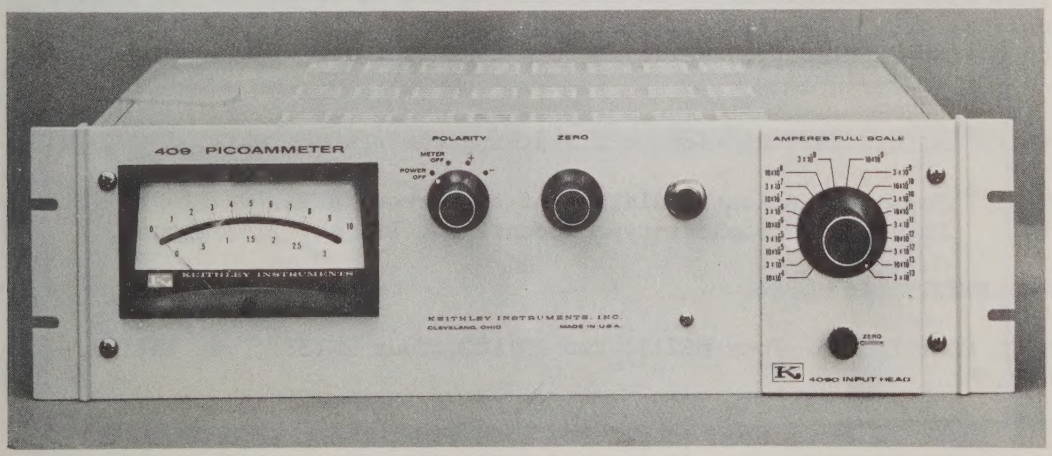

FIGURE 1. Keithley Model 409 Picoammeter. Instrument is shown with detachable angles for rack mounting.

b. When used with the Keithley Model 4103 Electronic Trip, the Picoammeter is useful for controlling nuclear reactors and for safety warning installations.

1-4. SPECIFICATIONS.

RANGES: 3×10^{-13} to 10×10^{-4} ampere full scale in twenty 1x and 3x overlapping ranges.

ACCURACY: $\pm$2% of full scale from 10×10^{-4} to 10×10^{-9} ampere; $\pm$4% of full scale from 3×10^{-9} to 3×10^{-13} ampere.

ZERO DRIFT: With source voltages greater than one volt and after a 30-minute warmup, zero drift is less than 1% of full scale per 24 hours on the 10×10^{-4} to 10×10^{-13} ampere ranges; less than 3% per 24 hours on 3×10^{-13} ampere range.

RISE TIME, MAXIMUM: Seconds, from 10% to 90% of final current reading:

Range, Ampere	No External Capacitance	With 50 pf Across Input	With 500 pf Across Input	With 5000 pf Across Input
3×10^{-13}	2.5	3.0	5.0	25.0
10×10^{-13}	1.5	2.0	2.5	12.0
10×10^{-12}	1.0	1.0	1.0	2.0
10×10^{-11}	0.25	0.25	0.25	0.5
10×10^{-10}	0.20	0.20	0.20	0.2
10×10^{-9}	0.20	0.20	0.20	0.2
10×10^{-8} and above	less than 0.001	less than 0.001	less than 0.001	less than 0.001

INPUT: Grid current is 2×10^{-14} ampere or less.* Change in input voltage drop is less than one millivolt for full-scale deflection on any range. Input resistance increases from one ohm at 10×10^{-4} ampere range to 3000 megohms at 3×10^{-3} ampere range in decade steps.

OUTPUT: A $\pm$3 volt output at up to one milliampere is developed for full-scale meter deflection. Output impedance is less than five ohms. Polarity is opposite to input polarity. Noise is less than 1% rms of full scale on any range.

ZERO CHECK: Allows zeroing without disturbing the test circuit.

CONNECTORS: Input: Teflon-insulated uhf-type receptacle.
Output: Microphone-type receptacle; Pin no. 2 is ground.

TUBE COMPLEMENT: One 5886.

TRANSISTOR COMPLEMENT: Four ME213, two 2N1183, four 2N1381, one 2N1535, one 2N651.

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* If the instrument has been stored for some time, the grid current will exceed the specification when first used, then decrease to below the specified amount after one to two hours of use. This is an inherent characteristic of the electrometer tube.

POWER: 105-125 volts or 210-250 volts, 50-1000 cps, 15 watts.

ACCESSORIES SUPPLIED: Mating input and output plugs.

DIMENSIONS: 5-1/4 inches high x 19 inches wide x 13-1/2 inches deep.

NET WEIGHT: 16 pounds.

1-5. ACCESSORIES. The following accessories may be used with the Model 409. Refer to Section 2 for operating and installing instructions.

a. Model 3000 Bench Mounting Kit converts the Picoammeter from a rack-mounted unit to one suitable for bench use. The kit contains four feet with rubber inserts, a tilt bail and a hooded top cover. As a bench model, the Picoammeter is 5-1/2 inches high x 17-1/2 inches wide x 13-1/2 inches deep.

b. Model 4103 Electronic Trip is a compact, self-contained transistorized amplifier designed to convert the Model 409 and other Keithley Micro-Microammeters into self-contained, automatic control systems. The Model 4103 requires only one adjustment, a trip level which can be set by the user. The exposed terminal strip permits the user to make rapid and easy changes in polarity, high or low trip level, and trip level sensitivity. The Model 409 can accomodate one or two Electronic Trips within its chassis. (Refer to Figure 11.)

1-6. EQUIPMENT SHIPPED. The Model 409 Picoammeter is factory-calibrated and is shipped with all components in place. The Picoammeter is shipped with separate rack angles for rack mounting. Refer to paragraph 2-6 for assembly instructions. The shipping carton also contains the Instruction Manual and mating plugs for the input and output receptacles.

FIGURE 2. Model 409 Picoammeter Equipped with Model 3000 Bench Mounting Kit.

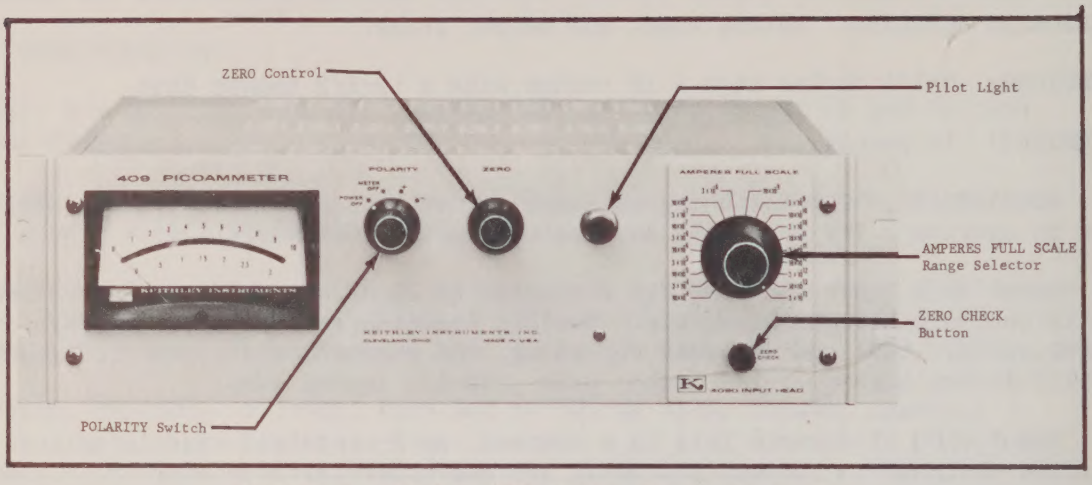


FIGURE 3. Model 409 Front Panel Controls.

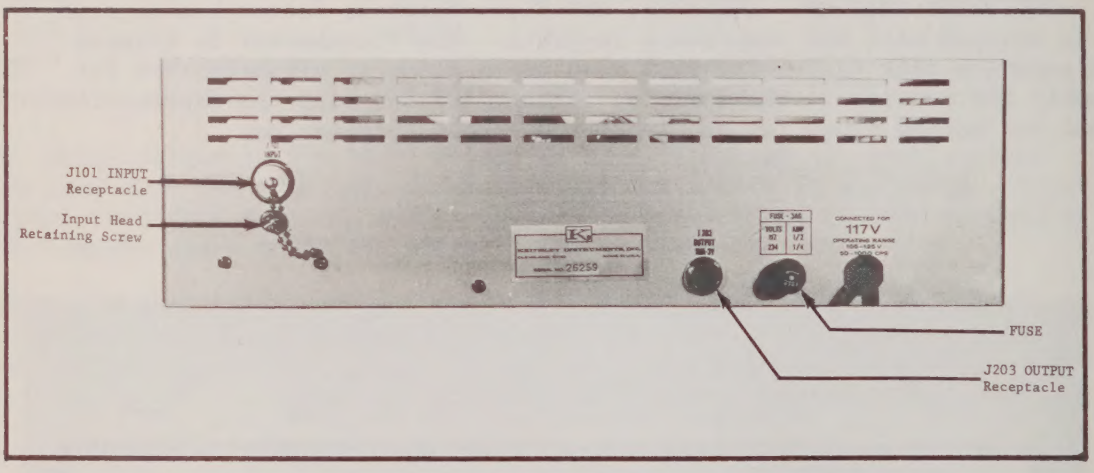


FIGURE 4. Model 409 Rear Panel Connections.

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS. (See Figure 3.)

a. POLARITY. The POLARITY Switch has four positions. The POWER OFF position shuts off the instrument. The METER OFF position disconnects the meter for recorder operation. The two polarity positions reverse the polarity of the meter.

b. ZERO. The 10-turn ZERO Control allows precise adjustment of the meter to zero on all ranges when the ZERO CK button is depressed.

c. AMPERES, FULL SCALE Range Selector. The Range Selector, located on the Model 4090 Input Head, adjusts the meter sensitivity over twenty ranges from 3 x 10^{-13} to 10 x 10^{-4} ampere full scale in 1x and 3x steps.

d. ZERO CK. Depressing the ZERO CHECK button effectively removes all current from the amplifier input and allows meter zeroing on any range. The switch cannot be locked in ZERO CK position.

2-2. REAR PANEL CONNECTIONS. (See Figure 4.)

a. J101 INPUT. A Teflon-insulated uhf-type coaxial input receptacle is provided on the back of the Input Head. It is accessible from the rear of the chassis when the Input Head is in place.

b. J203 OUTPUT. A 2-terminal receptacle provides $\pm$3 volts at full-scale meter deflection on all ranges for use with recorders. Pin no. 2 is at chassis ground. Polarity of the output is opposite in input current polarity. A 50-millivolt 100-ohm output is available on special order.

c. FUSE. A standard 3 AG fuse holder is provided. For 117-volt operation, use a 1/2 ampere, 3AG Slo Blow fuse; for 234 volts, use a 1/4 ampere, 3AG Slo Blow fuse.

d. Power Cord. The 3-wire power cord with the NEMA approved 3-prong plug provides a ground connection for the cabinet. An adapter for operation from 2-terminal outlets is provided.

2-3. INPUT CONNECTIONS.

a. Carefully shield the input connections and the current source being measured, since power line frequencies are within the pass band of the Picoammeter on several ranges. Unless the shielding is thorough, any alteration in the electrostatic field near the input circuitry will cause definite meter disturbances.

b. Use high resistance, low-loss materials — such as polyethylene, polystryene or Teflon — for insulation. Any coaxial cable used should be a low-noise type which employs a graphite coating between the dielectric and the surrounding shield braid. Amphenol-Borg Electronics Corporation, Microdot, Inc., and Simplex Wire and Cable Company make satisfactory types.

c. Any change in the capacitance of the measuring circuit to ground will cause extraneous disturbances. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. If a continuous vibration is present, it may appear at the output as a sinusoidal signal and other precautions may be necessary to isolate the instrument and the connecting cable from the vibration.

2-4. OPERATING PROCEDURES.

a. Connect the power cord to the power source; power line voltage and frequency range are indicated on the rear of the instrument. Turn the power on with the POLARITY Switch and allow 30 minutes for warmup. The instrument may be used immediately after it is turned on with only a slight derating of its drift specification.

b. Set the AMPERES Range Selector to the least sensitive position. Set the POLARITY Switch to the polarity of the input signal. Depress and hold down the ZERO CK Button and adjust the meter to zero with the ZERO Control. Advance the AMPERES Range Selector to the most sensitive range for an on-scale reading. Check the meter zero using the ZERO CK Button and, if necessary, adjust for zero.

2-5. RECORDER OUTPUT. The output of the Picoammeter for full-scale meter deflection on any range is ±3 volts at up to one milliampere. The output polarity is the opposite of the input signal polarity. One-milliampere Esterline-Angus and Texas Instruments recorders may be driven directly. Pin no. 2 is ground. The POLARITY Switch does not reverse the output polarity. To drive 10-or 50-millivolt recorders, divide the output with a suitable network. A 50-millivolt output at 100 ohms is also available on the Picoammeter if ordered.

NOTE

Further useful operating techniques and applications for the Model 409 are contained in the brochure "Electrometer Measurements" by Joseph F. Keithley, available upon request from Keithley Instruments, Inc.

2-6. BENCH AND RACK MOUNTING. (See Figure 5.)

a. Adding Rack Angles. The Picoammeter is supplied with all the necessary hardware for standard RETMA 19-inch rack mounting. The rack angles are packed separately to facilitate shipping.

1. Remove the four 8-32 slotted head screws (4) on the sides of the instrument.

2. Use the screws (4) to fasten the angles (3) to the instrument.

b. Bench Mounting Kit. If bench mounting of the Picoammeter is desired, use the Model 3000 Bench Mounting Kit. Assemble as follows:

1. Remove the four 10-32 slotted head screws (4) and, if attached, the rack angles (3). Remove the top cover assembly (1) by turning the two pawl-type fasteners one-half turn counter-clockwise. Remove the bottom cover assembly (2) the same way.

2. Attach the bail supports and two feet to the bottom cover (2), using two 8-32 x 1/2 screws, lockwashers and nuts, and two 6-32 x 3/8 screws, lockwashers and nuts. Fasten one 8-32 x 1/4 screw, head out, into each bail support with a lockwasher and nut.

3. Attach the other two feet, using two 8-32 x 1/2 screws, lockwashers, and nuts. Snap the bail into place. Push a rubber foot insert into each plastic foot.

4. Replace the bottom cover assembly on the instrument and secure in place with the two pawl-type fasteners.

5. Place the bench top cover assembly over the instrument. Use the four slotted head screws (4) to secure the cover to the instrument at the bottom corners of each side.

Item (See Fig. 5.)	Description	Keithley Part No.	Quantity
1	Cover Assembly with handles	14577C	1
2	Cover Assembly, Bottom (Supplied with unit)	14590B	1
-	Bail Support, Left	14703B	1
-	Bail Support, Right	14705B	1
-	Tilt Bail	14704B	1
-	Plastic Foot	FE-5	4
-	Rubber Foot Insert	FE-6	4
-	Screw, Phillips Head, 6-32 x 3/8	---	2
-	Screw, Phillips Head, 8-32 x 1/4	---	2
-	Screw, Phillips Head, 8-32 x 1/2	---	4
-	Hex Nut, 8-32	---	6
-	Hex Nut, 6-32	---	2
-	Internal tooth lockwasher, #8	---	6
-	Internal tooth lockwasher, #6	---	2
3	Angle, Rack (Supplied with rack-mounted units)	14624B	2
4	Screw, Phillips Head, 10-32 UNC- 2 x 1/4 (Supplied with unit)	---	4
5	Front Panel (Supplied with unit)	---	1

TABLE 1. Model 3000 Bench Mounting Kit Parts List.

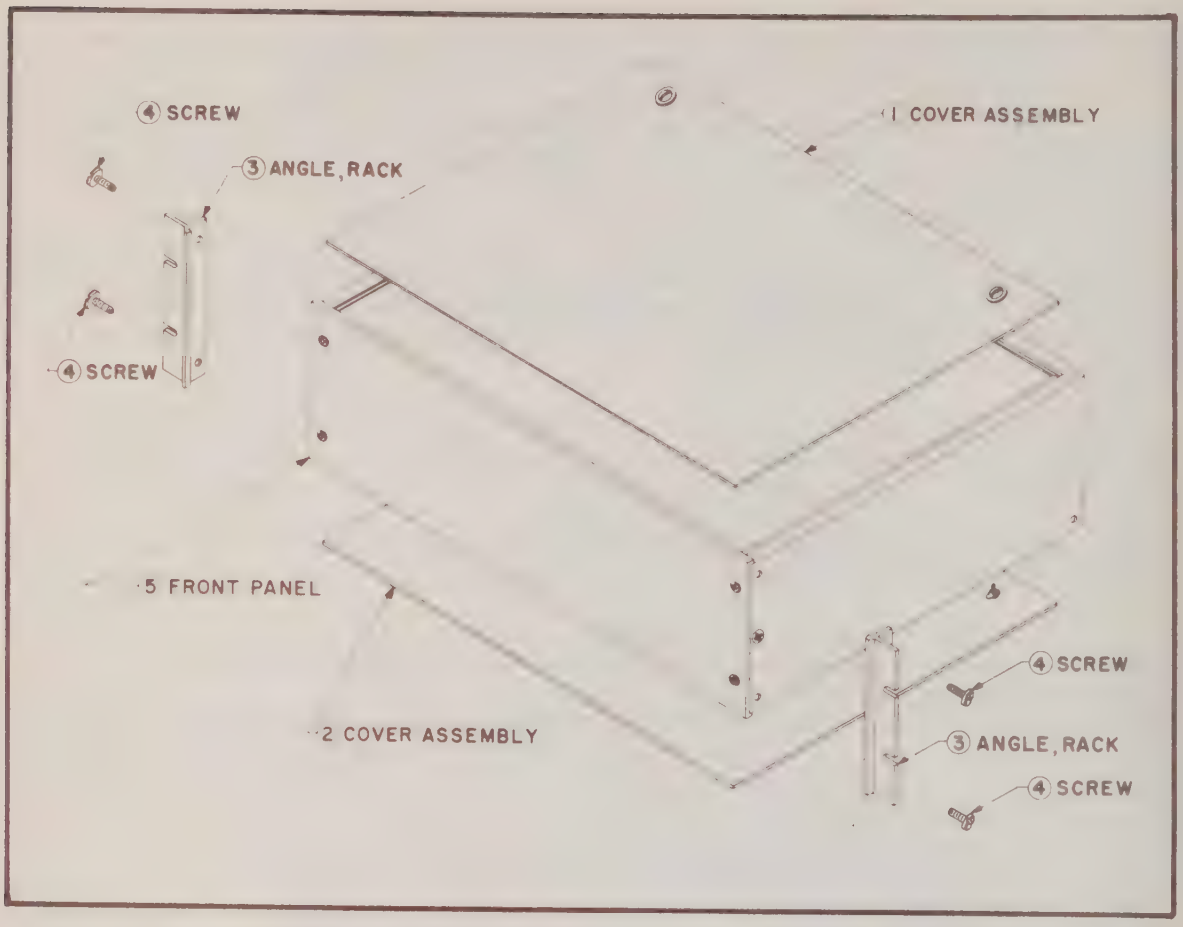


FIGURE 5. Exploded View for Assembling Model 3000 Bench Mounting Kit to Picoammeter.

2-7. 234-VOLT OPERATION. The instrument is shipped for use with a 117-volt power source unless otherwise ordered. To convert for use from a 234-volt power supply, refer to Figure 9. Remove two jumpers from PC-63, main chassis, and place one jumper between the indicated grommets.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Model 409 block diagram is shown in Figure 6. The signal to be measured is applied directly to the input of the high-gain dc amplifier and the feedback network. In the feedback network, an appropriate shunt resistor is selected with the AMPERES Range Selector. The output signal is read directly on the meter and is also available at the output terminals to drive recorders.

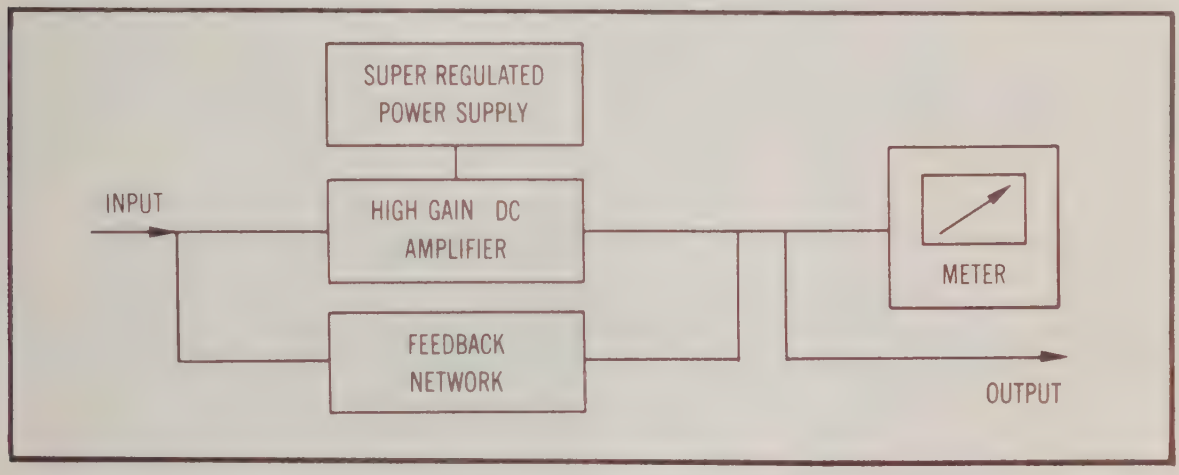


FIGURE 6. Model 409 Block Diagram.

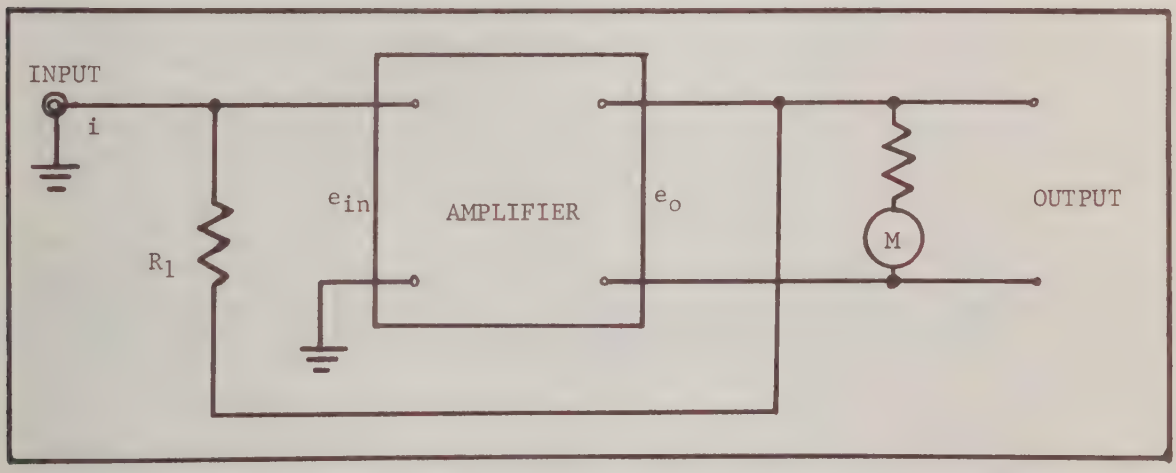


FIGURE 7. Amplifier and Feedback Circuit for Model 409. R_1 is the feedback resistor; e_{in} is the voltage across the amplifier input; and e_o is the voltage across the amplifier output.

3-2. AMPLIFIER AND FEEDBACK. The amplifier with the feedback circuit is shown in Figure 7. The feedback resistor, R_1, is the resistor selected by the AMPERES Range Selector. The amplifier is designed so that its output is the negative of the input signal. Assuming no current flow at the amplifier

input, the input current into the instrument, i, will flow through the feedback resistor R_1. If the gain of the amplifier is k and the feedback is negative

$$e_{in} = -e_o/k \qquad \text{Eq. 1}$$

where e_{in} is the voltage across the amplifier input;
e_o is the voltage across the amplifier output;
k is the open-loop gain of the amplifier.

Since the current must flow through R_1

$$i = \frac{-e_o + e_o/k}{R_1} \qquad \text{Eq. 2}$$

If the gain is large — for the Model 409, the gain is approximately 5,000 — then the current flow is

$$i = -e_o/R_1 \qquad \text{Eq. 3}$$

and a voltmeter at the amplifier output may be calibrated to read directly.

a. High Gain DC Amplifier. The amplifier, which is completely contained in the Input Head, consists of an electrometer tube input stage, an emitter follower input, a two-stage transistor amplifier and an emitter follower output.

NOTE

The circuit designations referred to in this section are for the schematic diagram 16809E found at the back of the Manual.

1. The input signal is applied to the grid of electrometer tube, V101, through an overload network consisting of capacitor C104 and resistor R118. Plate voltage for the electrometer tube is supplied through resistor R119; the filament current of 10 milliamperes is obtained from the +15 volt power supply through resistors R120 and R121. Adjusting potentiometer R214 (ZERO Control) zeros the meter by changing the screen voltage.

2. The electrometer tube V101 is directly coupled to the emitter follower, transistor Q101. Resistor R122 and capacitor C105 prevent oscillations. The output of Q101 is directly coupled to Q102. Identical transistors Q103 and Q104 provide temperature compensation for the first two transistor stages. The collector of Q102 is directly coupled to the base of the second stage amplifier, transistor Q105.

3. The output of transistor Q105 is directly coupled to the base of the emitter follower output stage using a power-type transistor Q106. The amplified signal is applied through resistors R216 and R217 to the meter, M201, and to the recorder output terminals, J203. The collector of Q106 and the collector resistor, R131, of the second amplifier stage are returned to the -10 volt supply to permit positive and negative outputs. Diode D101 and resistor R134 prevent overloading of the output stage.

b. Feedback Network. The amplifier output is divided by resistors R115, R116 and R117, and is fed back to the amplifier input through the range resistor, selected by positioning the AMPERES Range Selector S101.

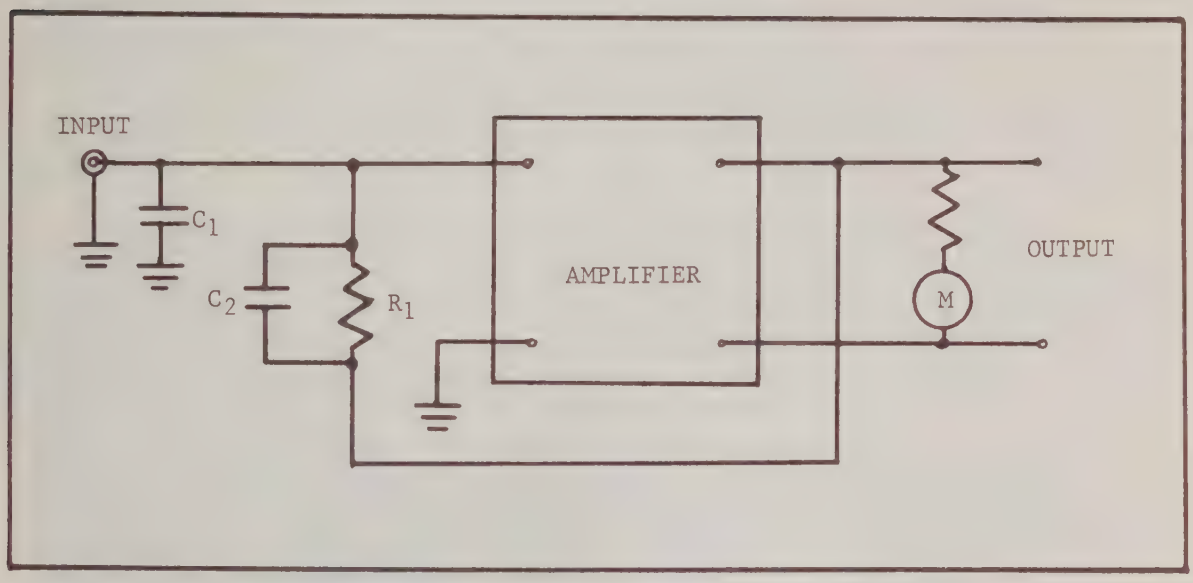


FIGURE 8. Feedback Network with Capacitance Indicated. C_1 is the input capacity; C_2 is the capacity across the feedback resistor; R_1 is the feedback resistor.

c. Damping. Referring to Figure 8, the time constant, T, of the circuit is:

$$T = R_1 \frac{C_1}{1 + k} + C_2 \qquad \text{Eq. 4}$$

where C_1 is the input capacity;
R_1 is the feedback resistor;
C_2 is the capacity across the feedback resistor;
k is the open loop gain of the amplifier.

Since the gain of the amplifier is at least 5,000, the effect of the input capacity on the time constant is very small, except at very low currents, and the time constant is determined primarily by the product R_1C_2. With a 10^{12} ohm resistor, which is used on the most sensitive range, this product amounts to a maximum of 2.5 seconds.

3-3. POWER SUPPLY. The power supply operates from the line voltage and furnishes +15 and -10 volts to the amplifier. Long-term dc stability of the power supply is within 0.1%. Output variations are less than 0.001% for 10% line voltage changes.

a. A 24-volt, 1-ampere output from the power transformer T201 is rectified by diodes D202 and D203 and is filtered by capacitor C202. The dc voltage across C202 is approximately 24 volts dc. The voltage is applied to the series transistor Q203.

b. To obtain a stable, accurate voltage, the output of the series transistor, Q203, is regulated by comparing a sample voltage from dividers R211 and R212 to the zener diode reference, D207. If a voltage difference exists, it is amplified by a differential amplifier consisting of transistors Q205 and Q206. The signal is further amplified by transistors Q204, Q201 and Q202. The output of Q202 is applied to the series transistor Q203 to nullify input variations. Capacitor C205 prevents high frequency oscillations. The +15 volts at the output of the regulator powers the hybrid amplifier and the pilot light.

c. Transistor Q204 operates at a high gain by connecting its collector load to a regulated supply. The circuit permits linear operation of Q203 with widely varying input voltages. To supply Q204, a 117-volt output of transformer T201 is half-wave rectified by diode D201 and is filtered by capacitor C203. Resistor R202 is a dropping resistor. The voltage across the zener diode D204 is a stable -10 volts, which is supplied to resistor R207, the collector load resistor of Q204.

d. Transistors Q201 and Q202 are cascaded emitter followers whose function is to increase the current gain of the series transistor, Q203. Resistors R203 and R205 are added to the circuit to provide stability at high temperatures. Resistors R204 and R206 and diode D205 provide current overload protection. Excessive current drawn from the power supply causes an increased voltage drop across R204, which forward biases diode D205, thus preventing the collector of Q204 from going more negative. Since the collector voltage cannot rise, further amplification is prevented and, therefore, further current increase is prevented.

SECTION 4. MAINTENANCE

4-1. GENERAL.

a. Section 4 contains the maintenance, troubleshooting and calibration procedures for the Model 409 Picoammeter. It is recommended that these procedures be followed as closely as possible to maintain the accuracy of the instrument.

b. The Model 409 requires no periodic maintenance beyond the normal care required of high-quality electronic equipment. Occasional verification of meter calibration should show any need for adjustment. The high-megohm resistor values should be checked every two or three years for specified accuracy on the 10×10^{-10} to 3×10^{-13} ampere ranges of the AMPERE Range Selector. Refer to paragraph 4-6.

4-2. PARTS REPLACEMENT. The Replaceable Parts List in Section 5 describes the electrical components of the Picoammeter. Replace components only as necessary. Use only reliable replacements which meet the specifications. The electrometer tube, V101, is aged and should be ordered only from Keithley Instruments, Inc. Transistors Q101 and Q104 are matched with respect to dc beta, as are transistors Q102 and Q103. Order these as pairs from Keithley Instruments.

4-3. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 409. Use the procedures outlined and use only specified replacement parts. Table 2 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, Keithley Instruments will service the instrument at its complete service facilities. Refer to the page at the back of the Manual for shipping instructions.

b. Paragraph 2-6 describes how to remove the cover from the Picoammeter. Table 3 contains the more common troubles which might occur with the instrument. If the repairs indicated in the table do not clear up the trouble, the difficulty will have to be found through a circuit-by-circuit check, such as

Instrument	Use
General Radio Variac	Check power supply line regulation.
Keithley Instruments Model 610A Electrometer	Measure dc voltages.
Keithley Instruments Model 660 Guarded DC Differential Voltmeter	Check power supply line regulation.
Transistor tester	Test transistors.

TABLE 2. Equipment Recommended for Troubleshooting Model 409.

Trouble	Probable Cause	Solution
One range out of calibration.	High-megohm resistor for range is not within specifications.	Refer to paragraph 4-6.
Meter will not zero.	Emmission of tube V101 has decreased out of range of ZERO Control.	Replace V101.
Meter out of calibration.	Potentiometer R217 is out of adjustment.	Refer to paragraph 4-7.
	Tube V101 or transistor Q101, Q102 or Q105 defective.	Test and replace faulty component. Check V101 against values in Table 4.

TABLE 3. Troubleshooting Table.

given in paragraph 4-4. Refer to the circuit description in Section 3 to find the more crucial components and to determine their function in the circuit. The complete circuit schematic diagram 16809E is found in Section 5.

4-4. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the fuse, line cord, power source and connections between the Input Head and the main chassis. If these are all found satisfactory, use the following procedures to isolate the trouble.

b. The schematic diagram indicates all tube element voltages and transistor terminal voltages referenced to chassis ground. Voltages are measured with the Keithley Model 610A Electrometer and should be ±10% of indicated value. The Picoammeter controls are set as follows to obtain the indicated value.

POLARITY +
AMPERES Range Selector 10×10^{-4}

c. Power Supply.

1. Remove the Input Head from the main chassis to avoid accidental damage to the amplifier. Loosen the retaining screw beneath the J203 OUTPUT receptacle on the rear panel (Figure 4) and pull out the Input Head.

2. Remove transistor Q203 from the circuit and turn on the instrument. Measure the voltage between chassis ground and the can terminal of capacitor C202 with the Model 610A Electrometer. Voltage should be approximately 28 volts dc.

3. Replace transistor Q203 in the circuit. Check the regulation of the power supply by using a General Radio Variac to supply the line voltage. Connect the Model 660 Differential Voltmeter across capacitor C206 and vary the line voltage from 105 to 125 volts. The voltage across the capacitor should be +15 volts dc, and it should not vary more than five millivolts with the line voltage changes. If no voltage is present or if the voltage is not properly regulated, check the regulator circuit. Particularly check diode D205 for a short and resistor R204 for an open circuit.

NOTE

When replacing the Input Head in the chassis, only hand tighten the retaining screw. Excessive tightening of the screw might cause the controls to bind.

d. Amplifier.

1. Remove the cover from the Input Head by removing the 10-32 slotted head screw on the back. Insert the Input Head into the chassis, leaving the cover off.

2. Set the AMPERES Range Selector to ZERO CK and set the POLARITY Switch to +. Check the electrometer tube filament current by measuring the voltage across resistor R120. The voltage should be approximately 2.5 volts. If there is no voltage, replace the electrometer tube.

3. Further troubleshooting of the amplifier is facilitated by defeating the feedback loop. Set the Range Selector to 3×10^{-13} and short the input to ground at the J101 INPUT receptacle. By effectively opening the feedback loop, disturbances near the output of the amplifier have less effect on the input stages.

4. With no feedback, any change in voltage at the input stage of the amplifier is amplified by successive stages, and it can be measured with the Model 610A Electrometer. The voltage change at the input stage can be produced by rotating the ZERO Control from a complete counter-clockwise position to a complete clockwise position. The first stage which does not produce a voltage change comparable to those shown in Table 4 should be checked for defective components. All voltages are measured from chassis ground. Base connections to the electrometer tube are shown in Figure 9. Check voltages in the order given in Table 4.

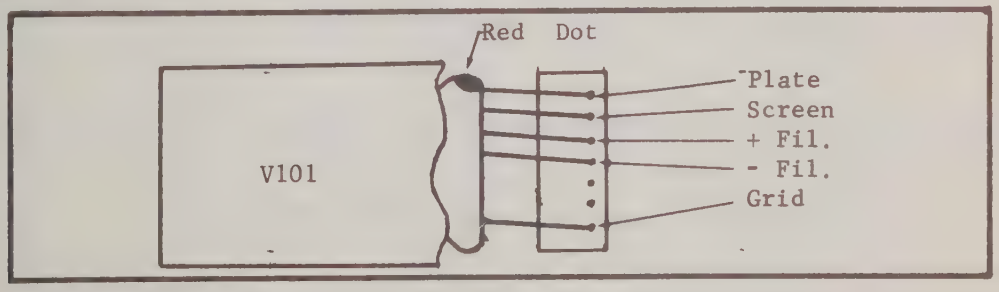


FIGURE 9. Base Connections for Electrometer Tube V101. Table 4 gives voltage values.

Circuit Location	Voltage With ZERO Control Completely Counter-clockwise (Volts)	Clockwise (Volts)
V101 Screen	+9.0	+14.0
V101 Plate	+10.0	+5.0
Q101 Emitter	+9.3	+4.4
Q102 Collector	+8.7	+15.0
Q102 and Q103 Emitters	+8.6	+7.2
Q103 Base	+8.0	no change
Q104 Base	+8.5	no change
Q105 Collector	+8.9	-5.6
Q106 Emitter	+5.2	-5.4

TABLE 4. Amplifier Voltage Changes with Feedback Loop Open. Adjusting the ZERO Control will produce the above values in a properly functioning instrument. Voltages should be checked in above order.

4-5. CALIBRATION PROCEDURES.

a. The following procedures are recommended for calibrating the Model 409. It is also recommended that the equipment listed in Table 5 be used. If proper facilities are not available or if difficulty is encountered, Keithley Instruments can recalibrate the instrument. Refer to the back of the Manual for shipping instructions.

b. Two procedures are covered in the following paragraphs: high-megohm resistor verification and meter calibration. These procedures cover the principal adjustable calibrations which will normally bring the instrument within specifications.

c. If the instrument is not within specifications after performing the calibration procedures, return the unit to Keithley Instruments for further checkout.

Instrument	Use
Keithley Instruments Model 515 Megohm Bridge.	Check high-megohm resistor values.
Keithley Instruments Model 660 Guarded DC Differential Voltmeter.	Measure voltage for meter calibration.

TABLE 5. Equipment Used in Calibration.

4-6. HIGH MEGOHM RESISTOR VERIFICATION.

a. Occasionally, it is necessary to check the value of the high-megohm resistors, R101 to R104, on the AMPERES Range Selector. The instrument should be within its rated accuracy for two or three years from the time it leaves the factory. After this, some of the resistors may drift out of tolerance and should be replaced.

b. To check these resistors, it is necessary to use a bridge capable of better than 1% accuracy up to 10^{12} ohms. An accurate megohm bridge, such as the Keithley Instruments Model 515 Megohm Bridge which is accurate to 0.25% for these ranges, is therefore necessary. If such equipment is not available, two procedures are recommended to check out the resistors:

1. Return the complete instrument or just the Input Head to the factory for resistor calibration.

2. Replace the high-megohm resistors periodically with a certified set from Keithley Instruments to assure absolute calibration accuracy.

4-7. METER CALIBRATION.

a. The meter calibration will bring the instrument within the specified accuracy if all circuits are operating properly. The only instrument needed for the calibration is a Model 660 DC Voltmeter or an equivalent 0.02% instrument.

b. Procedures.

1. Connect the Model 660 DC Voltmeter to the Picoammeter J203 OUTPUT receptacle.

2. Set the Picoammeter POLARITY Switch to + and the AMPERES Range Selector to 10 x 10^{-9}. Depress and keep depressed the ZERO CK Button.

3. Rotate the ZERO Control clockwise until exactly -3 volts is indicated at the output terminals. If a full 3-volt output cannot be obtained with the ZERO Control, set the AMPERES Range Selector to 10 x 10^{-4} ampere and apply enough current at the input terminals to produce a 3-volt output. Adjust the METER CAL. potentiometer, R217, located on the main printed circuit board, for full-scale deflection of the panel meter.

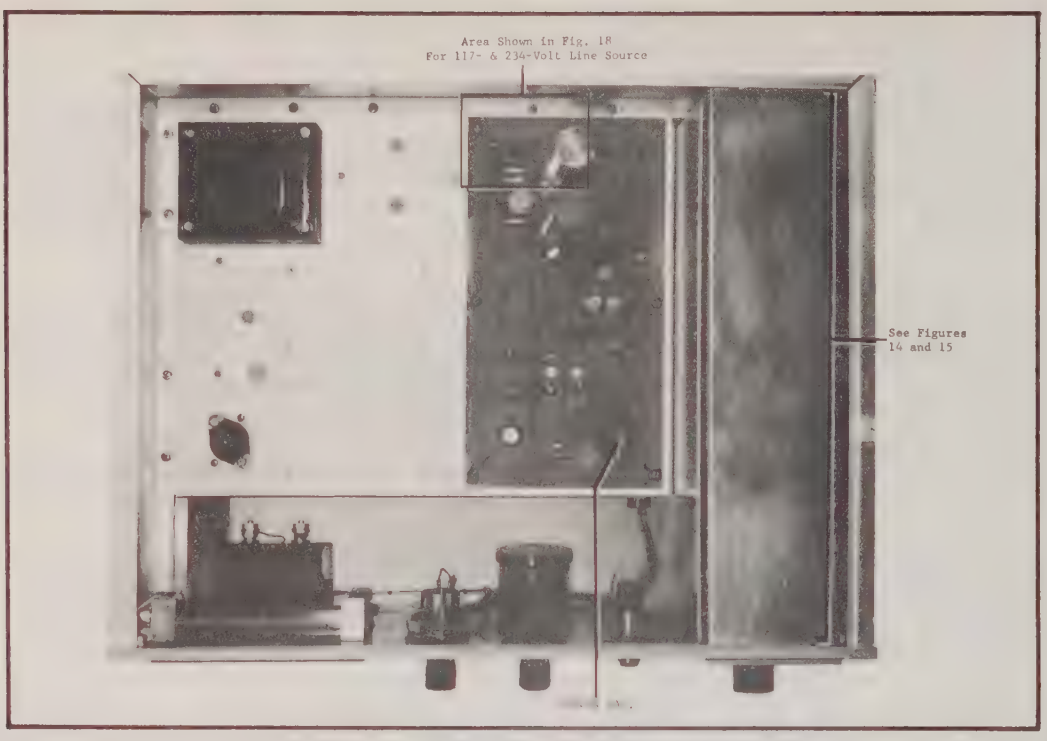


FIGURE 10. Top View of Model 409 with Cover Removed. Refer to Figure 11 for component location on the main chassis.

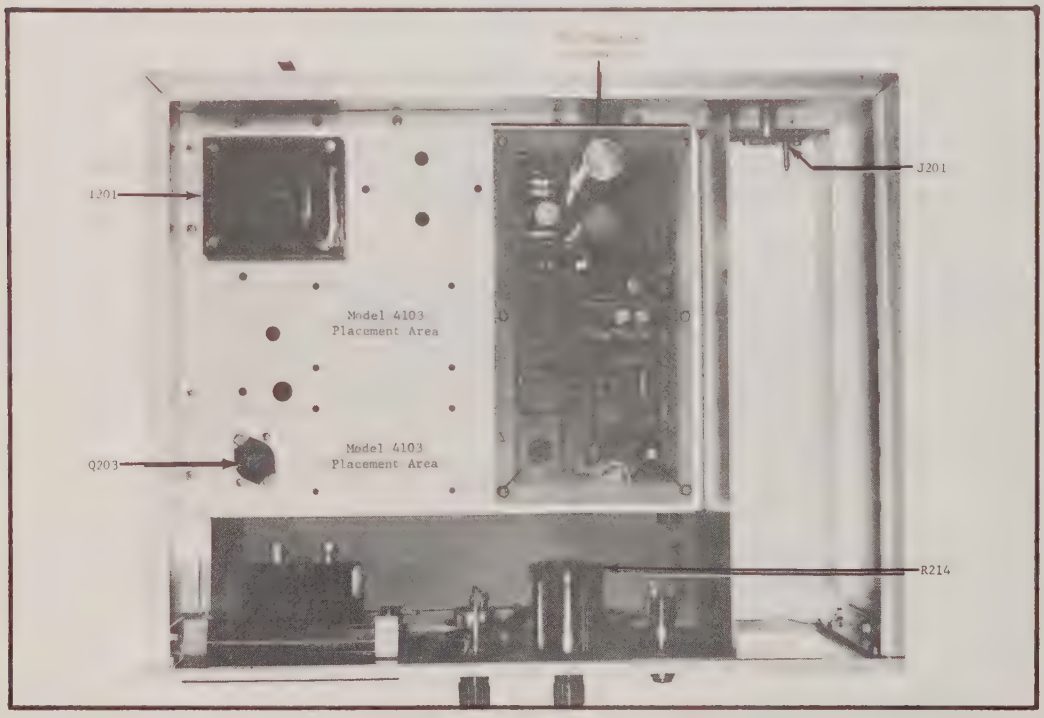


FIGURE 11. Top View of Model 409 Main Chassis. Circuit designations shown correspond to those of the Replaceable Parts List and the Schematic Diagram.

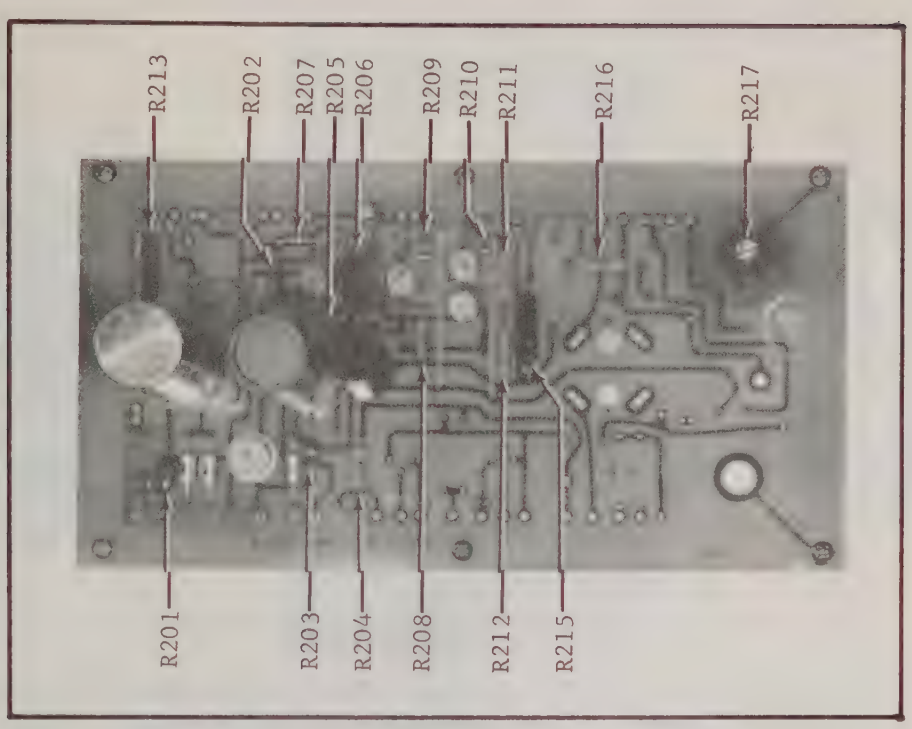


FIGURE 12. Resistor Locations on PC-63, Model 409 Main Chassis.

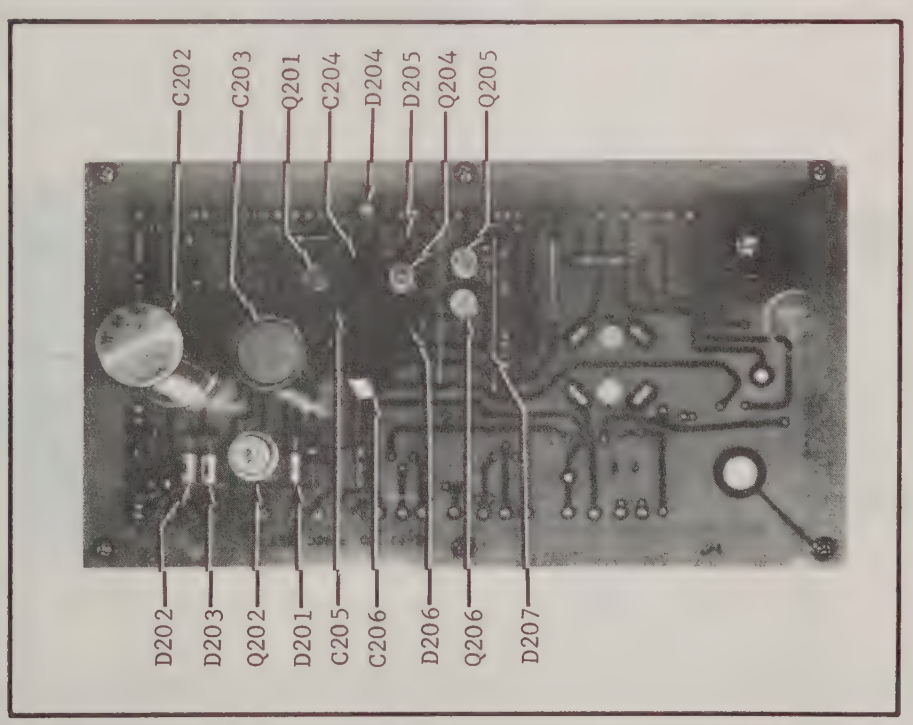


FIGURE 13. Capacitor, Diode and Transistor Locations on PC-63, Model 409 Main Chassis.

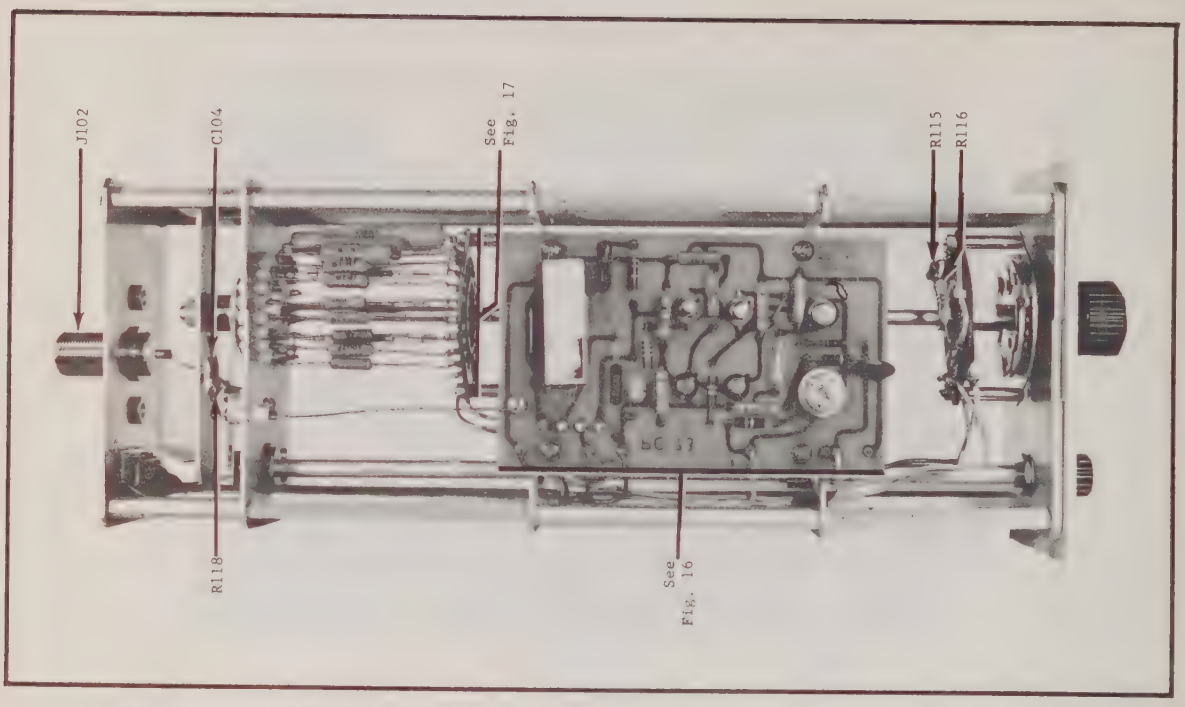


FIGURE 14. Component Locations on Model 4090 Input Head. (Shown from top side of PC-73.)

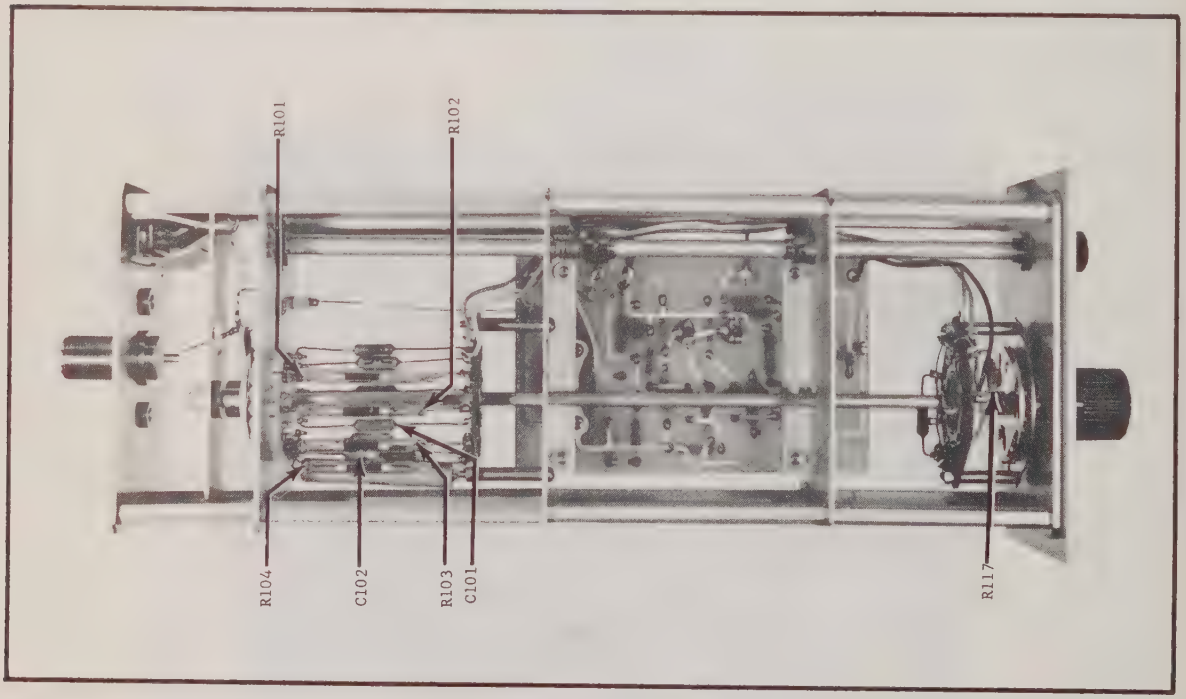


FIGURE 15. Component Locations on Model 4090 Input Head. (Shown from bottom of PC-73.)

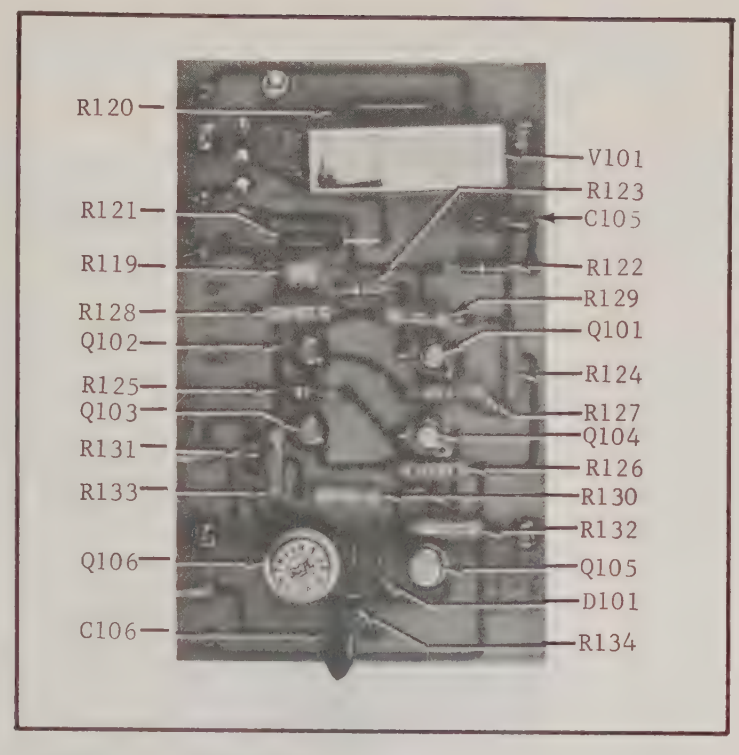


FIGURE 16. Component Locations on PC-73, Model 4090 Input Head.

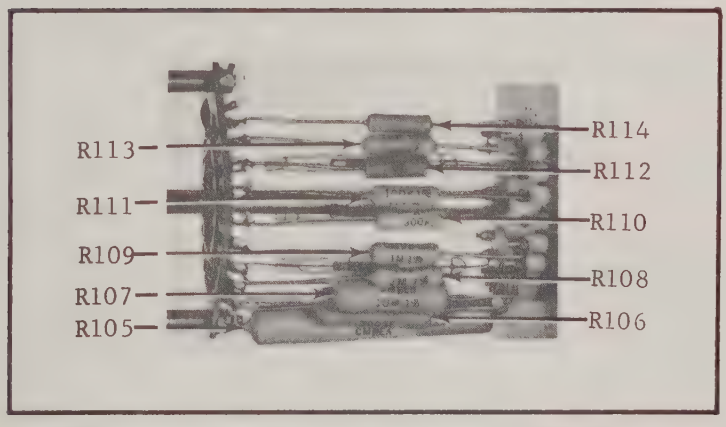


FIGURE 17. Component Locations on AMPERES Range Selector, Model 4090 Input Head.

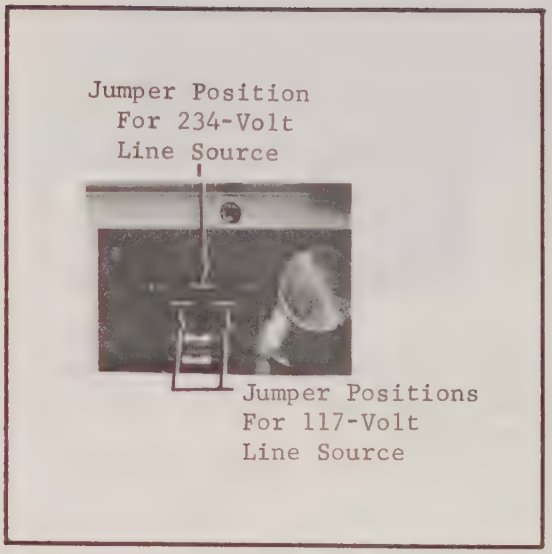


FIGURE 18. Jumper Connections for 117- and 234-Volt Line Source. The jumpers which should be used for either 117- or 234-volts are shown above. Refer to Figure 10 for position area shown above within the Model 409.

SECTION 5. REPLACEABLE PARTS LIST

5-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 409. The List gives the circuit designation, the part description, a suggested manufacturer and the Keithley Part Number. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 7.

5-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through:

Sales Service Department
Keithley Instruments, Inc.
12415 Euclid Avenue
Cleveland, Ohio 44106
Telephone 795-2666, Area Code 216

amp	ampere	Mil. No.	Military Type Number
		My	Mylar
CerD	Ceramic, Disc		
Comp	Composition	Ω	ohms
DCb	Deposited Carbon	PMP	Metalized paper, phenolic case
		Poly	Polystyrene
EMC	Electrolytic, metal cased	p	pico (10^{-12})
f	farad	μ	micro (10^{-6})
k	kilo (10^{3})	v	volt
		Var	Variable
M or meg	mega (10^{6}) or megohms		
m	milli (10^{-3})	w	watt
Mfg.	Manufacturer	WW	Wirewound
MtF	Metal Film	WWVar	Wirewound Variable

TABLE 6. Abbreviations and Symbols.

MODEL 409 AND MODEL 4090 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 16809E for circuit designations.)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
C101	5 pf	200 v	Poly	00686	C31-5P
C102	50 pf	200 v	Poly	00686	C31-50P
C103	500 pf	200 v	Poly	00686	C31-500P
C104	.0022 µf	1000 v	CerD	56289	C72-.0022
C105	.22 µf	50 v	My	84411	C41-.22
C106	.0047 µf	600 v	CerD	72982	C22-.0047
C201	.01 µf	600 v	CerD	72982	C22-.01
C202	500/500 µf	35 v	EMC dual	53021	C20-500-500
C203	40 µf	200 v	EMC	53021	C19-40
C204	100 µf	15 v	PMP	56289	C93-100
C205	.01 µf	600 v	CerD	72982	C22-.01
C206	500 µf	25 v	PMP	56289	C94-500
C207	**.0047 µf	600 v	CerD	72982	C22-.0047

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.
D101	Silicon	1N482	94145	RF-14
D201	Silicon	1N3255	02735	RF-17
D202	Silicon	1N3253	02735	RF-20
D203	Silicon	1N3253	02735	RF-20
D204	Zener	1N1314	99942	DZ-2
D205	Silicon	1N482	94145	RF-14
D206	Silicon	1N482	94145	RF-14
D207	Zener	1N936	04713	DZ-5

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
--	Pilot Light Holder (Mfg. No. 81410-212)	72619	PL-5
DS-201	Bulb, Miniature bayonet base (Mfg. No. 313)	08804	PL-21
F-201 (117 v)	Fuse, Slo Blow, 0.5 amp, 3 AG	75915	FU-4
F-201 (234 v)	Fuse, Slo Blow, 0.25 amp, 3 AG	75915	FU-17
--	Fuse holder	75915	FH-3

** Used only on Models with 50-mv output.

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
J101	Receptacle, uhf, INPUT	80164	CS-134
--	Plug, uhf, Mate of J101, Mil. No. 49190 (Mfg. No. 5127)	91737	CS-49
--	Cap for Input Receptacle	91737	CAP-4
J102	Plug (Mfg. No. DA-15P)	71468	CS-87
J201	Receptacle (Mfg. No. DA-15S)	71468	CS-86
J203	Receptacle, Microphone, OUTPUT (Mfg. No. 80MC2F)	02660	CS-32
--	Plug, Microphone, Mate of J203 (Mfg. No. 80MC2M)	02660	CS-33
M201	Meter	80164	ME-35
P201	Power Cord, 6 feet	80164	CO-2
--	Strain Relief	80164	CC-7
--	3-wire Adapter (accessory)	80164	CO-4
S101	Rotary Switch less components, AMPERES FULL SCALE	80164	SW-156
--	Rotary Switch with components, Amperes Switch	80164	16900B
--	Knob Assembly, Amperes Switch	80164	16338A
S102	Push Switch, ZERO	80164	16373A
S201	Rotary Switch less components, POLARITY	80164	SW-113
--	Knob Assembly, Polarity Switch	80164	14838A
--	Knob, Zero Control	80164	15110A
T201	Power Transformer	80164	TR-45

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
R101	10^{12} Ω	+3%, -0%	HiMeg	63060	R20-10^{12}
R102	10^{11} Ω	+3%, -0%	HiMeg	63060	R20-10^{11}
R103	10^{10} Ω	+3%, -0%	HiMeg	63060	R20-10^{10}
R104	10^{9} Ω	+3%, -0%	HiMeg	63060	R20-10^{9}
R105	100 MΩ	1%, 2 w	DCb	00327	R14-100M
R106	30 MΩ	1%, 1 w	DCb	00327	R13-30M
R107	10 MΩ	1%, 1 w	DCb	00327	R13-10M
R108	3 MΩ	1%, 1/2 w	DCb	00327	R12-3M
R109	1 MΩ	1%, 1/2 w	DCb	00327	R12-1M
R110	300 kΩ	1%, 1/2 w	DCb	00327	R12-300K

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
R111	100 kΩ	1%, 1/2 w	DCb	00327	R12-100K
R112	30 kΩ	1%, 1/2 w	DCb	00327	R12-30K
R113	10 kΩ	1%, 1/2 w	DCb	00327	R12-10K
R114	3 kΩ	1%, 1/2 w	DCb	00327	R12-3K
R115	2 kΩ	1%, 1/2 w	DCb	00327	R12-2K
R116	700 Ω	1/2%, 1/4 w	MtF	75042	R75-700
R117	300 Ω	1/2%, 1/4 w	MtF	75042	R75-300
R118	22 MΩ	10%, 1/2 w	Comp	01121	R1-22M
R119	121 kΩ	1%, 1/2 w	DCb	75042	R94-121K
R120	250 Ω	1%, 1 w	WW	15909	R58-250
R121	1.2 kΩ	1%, 1 w	WW	15909	R58-1.2K
R122	*330 Ω	10%, 1/2 w	Comp	44655	R1-330
R123	33 kΩ	10%, 1/2 w	Comp	01121	R1-33K
R124	75 kΩ	1%, 1/2 w	DCb	00327	R12-75K
R125	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K
R126	3.4 kΩ	1%, 1/2 w	DCb	00327	R12-3.4K
R127	75 kΩ	10%, 1/2 w	Comp	01121	R12-75K
R128	4.7 kΩ	1%, 1/2 w	DCb	00327	R12-4.7K
R129	6 kΩ	1%, 1/2 w	DCb	00327	R12-6K
R130	1 kΩ	1%, 1/2 w	DCb	00327	R12-1K
R131	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K
R132	3.4 kΩ	1%, 1/2 w	DCb	00327	R12-3.4K
R133	2.5 kΩ	1%, 1/2 w	DCb	00327	R12-2.5K
R134	100 Ω	1%, 1/2 w	DCb	00327	R12-100
R201	3 Ω	5%, 3 w	WW	44655	R92-3
R202	10 kΩ	5%, 3 w	WW	44655	R92-10K
R203	820 Ω	10%, 1/2 w	Comp	01121	R1-820
R204	1 Ω	1%, 1/2 w	DCb	00327	R12-1
R205	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K
R206	1.2 kΩ	10%, 1/2 w	Comp	44655	R1-1.2K
R207	10 kΩ	10%, 1/2 w	Comp	01121	R1-10K
R208	300 Ω	1%, 1/2 w	DCb	00327	R12-300
R209	3.9 kΩ	10%, 1/2 w	Comp	01121	R1-3.9K
R210	3.9 kΩ	10%, 1/2 w	Comp	01121	R1-3.9K
R211	600 Ω	1%, 1/2 w	DCb	00327	R12-600
R212	900 Ω	1%, 1/2 w	DCb	00327	R12-900
R213	350 Ω	1%, 1 w	WW	15909	R58-350
R214	200 Ω	3%, 5 w	WWVar	73138	RP4-200
R215	50 Ω	1%, 1 w	WW	15909	R58-50
R216	2.5 kΩ	1%, 1/2 w	DCb	00327	R12-2.5K
R217	1 kΩ	10%, 2 w	WWVar	71450	RP3-1K

* Nominal value, factory selected.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
R218	**5.9 kΩ	0.1%, 1 w	WW	15909	R70-5.9K
R219	**100 Ω	0.1%, 1 w	WW	15909	R70-100

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.
Q101	*ME-213	80164	TG-21
Q102	*ME-213	80164	TG-21
Q103	*ME-213	80164	TG-21
Q104	*ME-213	80164	TG-21
Q105	2N651	04713	TG-9
Q106	2N1183	02735	TG-11
Q201	2N1381	01295	TG-8
Q202	2N1183	02735	TG-11
Q203	2N1535	04713	TG-7
Q204	2N1381	01295	TG-8
Q205	2N1381	01295	TG-8
Q206	2N1381	01295	TG-8

VACUUM TUBES

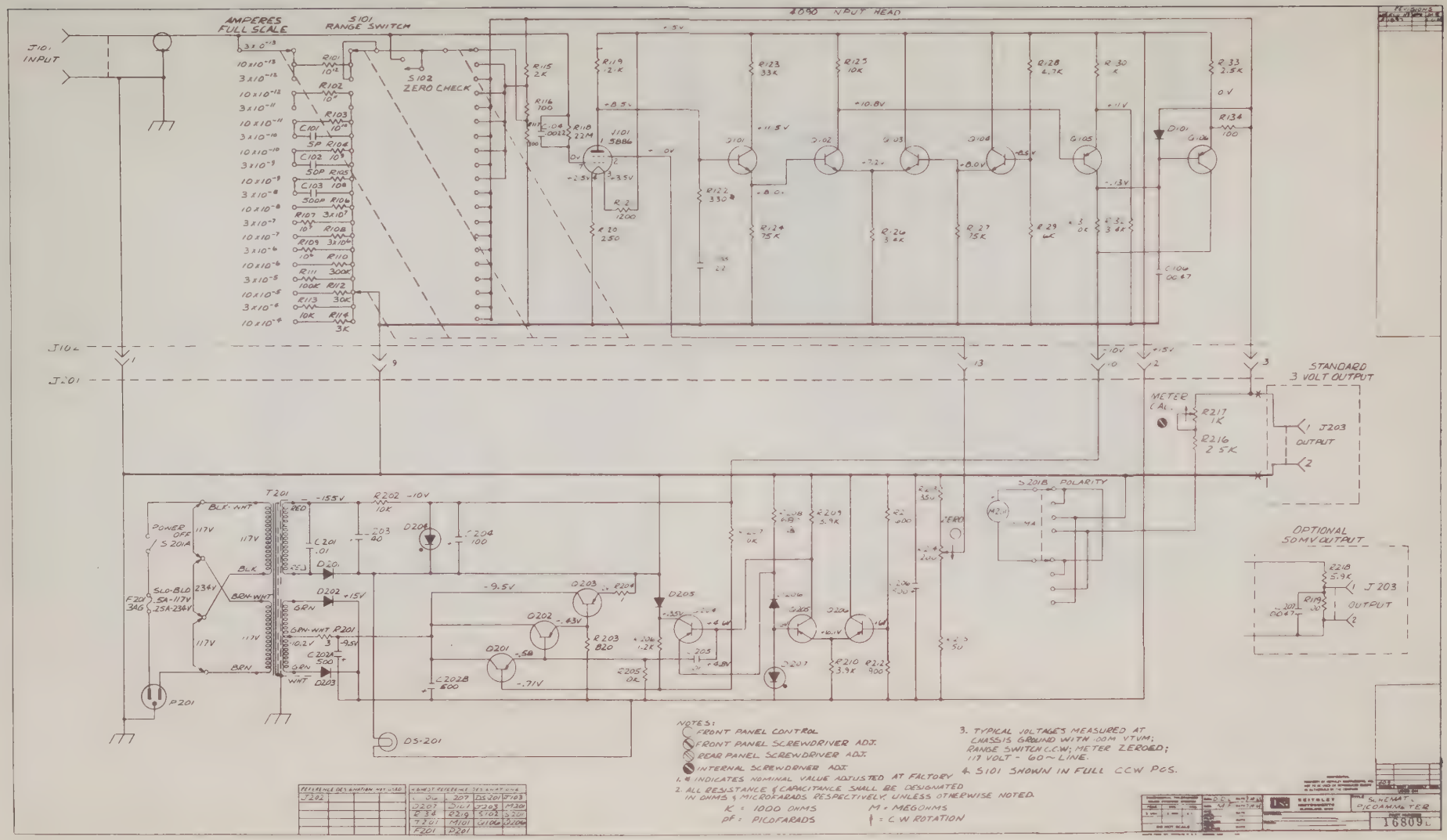
Circuit Desig.	Number	Mfg. Code	Keithley Part No.
V101	5886	80164	EV-5886-9

*Transistors Q101 and Q104 are matched to each other; transistors Q102 and Q103 are matched to each other. Order replacements for each pair through Keithley Instruments.

**Used only on Models with 50-mv output.

00327	Welwyn International, Inc. Cleveland, Ohio
00686	Film Capacitors, Inc. New York, N. Y.
01121	Allen-Bradley Corp. Milwaukee, Wisc.
01295	Texas Instruments, Inc. Semi-Conductor Products Div. Dallas, Texas
02660	Amphenol Connector Division Amphenol-Borg Electronics Corp. Chicago, Illinois
02735	Radio Corp. of America RCA Semiconductor & Materials Div. Somerville, N. J.
04713	Motorola, Inc. Semiconductor Products Division Phoenix, Ariz.
08804	General Electric Co. Lamp Division Cleveland, Ohio
15909	Daven Co. Livingston, N. J.
44655	Ohmite Mfg. Co. Skokie, Ill.
53021	Sangamo Electronics Co. Springfield, Ill.
56289	Sprague Electric Co. North Adams, Mass.
63060	Victoreen Instrument Co. Cleveland, Ohio
71450	CTS Corp. Elkhart, Ind.
71468	Cannon Electric Co. Los Angeles, Calif.
72619	Dialight Corp. Brooklyn, N. Y.
72982	Erie Resistor Corp. Erie, Pa.
73138	Helipot Division Beckman Instruments, Inc. Fullerton, Calif.
75042	International Resistance Co. Philadelphia, Pa.
75915	Littelfuse, Inc. Des Plaines, Ill.
77764	Resistance Products Co. Harrisburg, Pa.
80164	Keithley Instruments, Inc. Cleveland, Ohio
84411	Good-All Electric Mfg. Co. Ogallala, Nebr.
91737	Gremar Mfg. Co., Inc. Wakefield, Mass.
94145	Raytheon Co. Semiconductor Division Newton, Mass.
99942	Hoffman Electronics Corp. Semiconductor Division El Monte, Calif.

TABLE 7. Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)


AMPERES FULL SCALE
S101 RANGE SWITCH
J101 INPUT
S102 ZERO CHECK
6090 INPUT HEAD
J102
J201
STANDARD 3 VOLT OUTPUT
METER CAL.
R217 1K
R216 2.5K
J203 OUTPUT
S201B POLARITY
OPTIONAL 50MV OUTPUT
R218 5.9K
R219 50
T201
POWER OFF S201A
F201 3AG .5A-117V .25A-234V
P201
DS-201
ZERO
NOTES:
FRONT PANEL CONTROL
FRONT PANEL SCREWDRIVER ADJ.
REAR PANEL SCREWDRIVER ADJ.
INTERNAL SCREWDRIVER ADJ.
1. ⊕ INDICATES NOMINAL VALUE ADJUSTED AT FACTORY
2. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY, UNLESS OTHERWISE NOTED.
K = 1000 OHMS
M = MEGOHMS
pF = PICOFARADS
3. TYPICAL VOLTAGES MEASURED AT CHASSIS GROUND WITH .00M VTVM; RANGE SWITCH C.C.W; METER ZEROED; 117 VOLT - 60 - LINE.
4. S101 SHOWN IN FULL CCW POS.
SCHEMATIC PICOAMMETER
16809

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the plant directly, DDD 216-795-2666. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has authorized field repair facilities in Los Angeles and Albuquerque.

To insure prompt repair or recalibration service, please contact your local field representative, or the plant directly, before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

T. LOUIS SNITZER CO.
ELECTRONIC ENGINEERING REPRESENTATIVES
15 NORTH 40th PLACE
PHOENIX, ARIZONA 85034
TELEPHONE 273-1673

KEITHLEY INSTRUMENTS, INC.
12415 EUCLID AVENUE CLEVELAND 6, OHIO